Magnetron Injection Gun Measurements

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***Abstract*— Several magnetron injection gun cathodes have been measured for temperature and emission uniformity. The measurements confirm results in Russia that the quality of many MIG cathodes is not sufficient for efficient gyrotron operation. This presentation will present recent cathode measurements and identify known issues. A design will be presented that provides a solution for several of these issues.**

I. Program Description

CALABAZAS Creek Research, Inc. (CCR) is continuing its research to improve the quality of magnetron injection gun cathodes for gyrotrons and gyroklystrons. This research began in 2001 with funding from the U.S. Department of Energy and is continuing on CCR funds. Results indicate that problems with MIG cathodes remain, despite many improvements in fabrication facilities and equipment. A recent cathode purchased by the Massachusetts Institute of Technology exhibited a 24^{o}C temperature variation azimuthally around the emitter. Emission measurements indicated a factor of four variation in emission that only partially corresponded to the temperature variation. This indicates problems with both the cathode temperature and the work function.

II. Test Facilities

CCR's test facilities consist of a vacuum bell jar for processing and heating cathodes to the operating temperature and a MIG test chamber for detailed temperature and emission measurements over the cathode surface. A photograph of the MIG chamber test set-up is shown in Figure 1. Both the bell jar and the test chamber are equipped with residual gas analyzers and have base vacuum pressures below 1.5 $(10)^{-8}$ Torr.

The MIG test chamber measures emission at up to eight locations across the width of the emitter and in increments as small as 0.5^{o} azimuthally around the cathode. The emission current is collected by a probe that integrates the current during the cathode voltage pulse of 1-10 microseconds. This integrated value is converted to a digital value by a multi-channel analog-to-digital converter and read by a personal computer. The information is plotted in real time and displayed on the computer monitor. The computer averages several current emission values at each azimuthal position before rotating the cathode by a user-specified angle. This process continues until the cathode is rotated 360 degrees or by a user-specified amount. A Micron 680 infrared probe measures cathode temperature near the axial center of the emitter strip. The signal from the probe controller is read and stored by the computer at each azimuthal location along with the emission measurements. A graphical user interfaces facilitates measurement setup, data storage, and post processing.

III. Measurements

Since the measurement facility was initially completed, approximately seven cathodes have been analyzed. Currently two more are scheduled for measurement during the summer of 2008. It is interesting that the best performance measured to date was on the second cathode tested, which was in 2004. That was also the largest cathode tested. Recent results have failed to detect any significant improvement in performance.

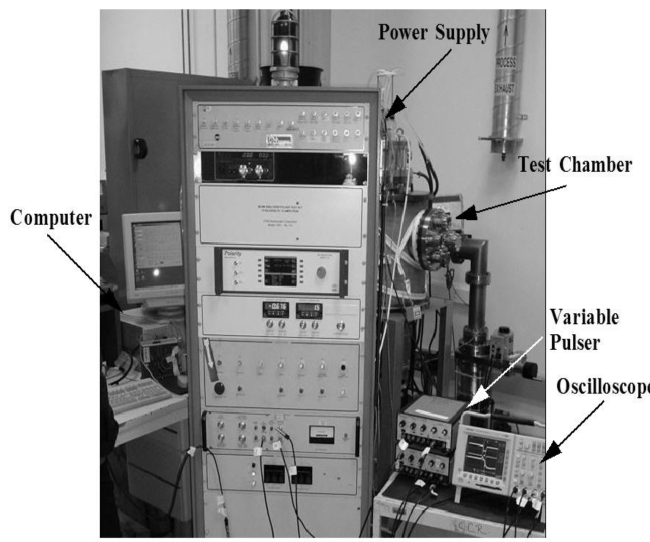

Figure 1. Test facilities for measuring temperature and emission uniformity of magnetron injection gun cathodes.

Figure 2 shows the temperature variation around the MIT cathode mentioned in Section I and Figure 3 shows the corresponding emission measurements. It is possible that sections of the cathode may not be fully activated. This would misrepresent the final performance of the cathode; however, the temperature variation should not change.

CCR measured a cathode-heater assembly fabricated in its own laboratory. The assembly includes a free standing heater coil that can be modified to correct for temperature variations. A photograph of this assembly is shown in Figure 4 and the measured temperature and emission is shown in Figures 5 and 6, respectively. A feature of this design is that the azimuthal

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heating profile can be adjusted by shifting of the heater coils, which are attached by moly wires to the heat shield support.

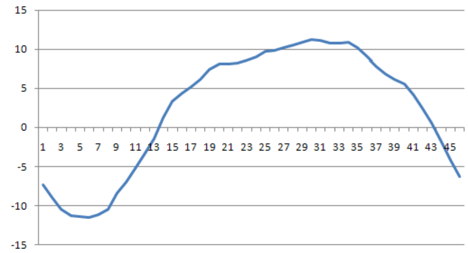

Figure 2. Temperature variation in degrees Centigrade of MIT MIG cathode.

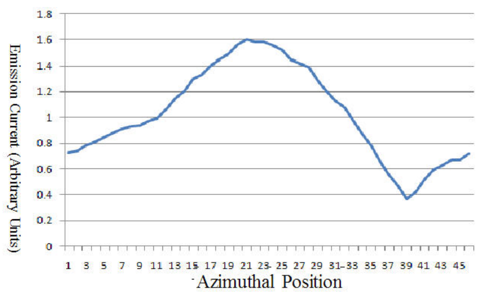

Figure 3. Emission measurements of MIT MIG cathode.

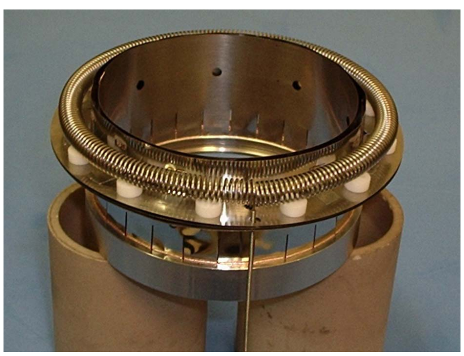

Figure 4. Heater assembly developed by CCR with adjustability of the azimuthal heating profile.

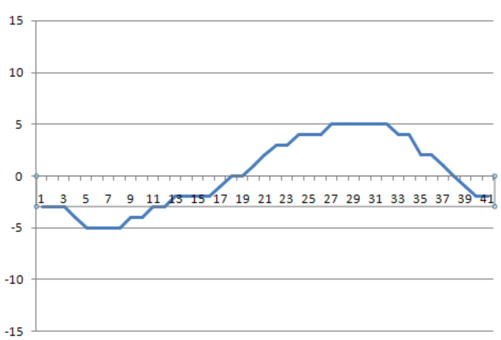

Figure 5. Initial temperature measurements of heater-cathode assembly with coils as shown in Figure 4. The vertical scale is temperature in degrees C, and the horizontal scale represents the 360 degree positions of the cathode. The dip in temperature on the left is at the heater lead location. The stair-step profile is a function of the temperature measurement resolution.

Interestingly, the emission measurement, shown in Figure 6, exhibited significant local variations. This pattern was repeatable and roughly similar between adjacent probes scanning the cathode surface.

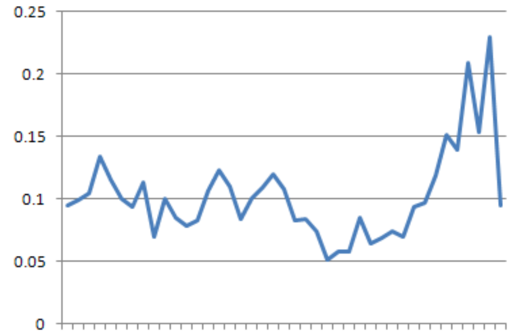

Figure 6. Current emission measured by probe #4 for CCR heater cathode assembly. The vertical scale uses arbitrary units and shows relative emission from the surface. The horizontal axis represents a 360 degree scan.

The next step in this development will be to shift the heater coils to reduce heat in the high emission areas and increase heat where the emission is lower.

CCR is also preparing to measure temperature and emission of a MIG for a 200 MW, pulsed klystron at L-Band. A photograph of the cathode is shown in Figure 7. This cathode is more than 1.5 inches in axial extent and requires significant heater power. It is questionable if the MIG chamber components can tolerate the expected radiated heat. Available test results will be presented.

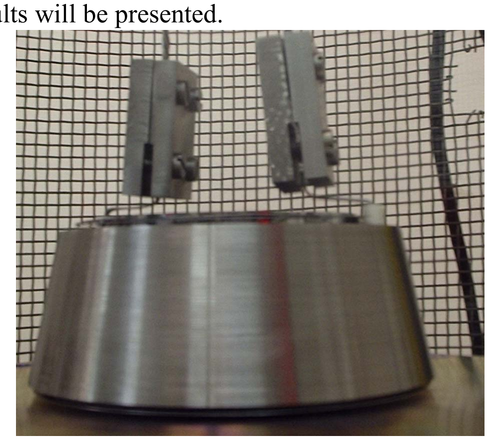

Figure 7. Magnetron injection gun cathode for a 200 MW, L-Band klystron.

IV. SUMMARY

Emission and temperature measurements are continuing to ensure cathodes will achieve the required specifications for operation in high power RF sources. This information is also used to investigate unacceptable behavior and develop improved design, processes and procedures. Recent results indicate there is significant variability in cathode performance.

V. ACKNOWLEDGEMENTS

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